DOCUMENT RESUME

ED 162 835 SE 025 032

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TITLE	Land Application of Wastes: An Educational Program. Monitoring at Land Application Sites - Module 18, Objectives, Script, and Booklet.
INSTITUTION	State Univ. of New York, Ithaca. Coll. of Agriculture and Life Sciences at Cornell Univ.
SPONS AGENCY	Corps of Engineers, Washington, D.C.; Environmental Protection Agency, Washington, D. C.
PUB DATE	Jan 78
GRANT	EPA-T-900500
NOTE	71p.; For related documents, see SE 025 014-035; Not available in hard copy due to copyright restrictions; Contains occasional light and broken type
AVAILABLE FROM	Van Nostrand Reinhold, 450 West 33rd Street, New York, N.Y. 10001
EDRS PRICE	MF-$0.83 Plus Postage. BC Not Available from EDRS.
DESCRIPTORS	*Environment; *Land Use; *Learning Modules; Pollution; Sanitation; Science Education; *Waste Disposal; Wastes; *Water Pollution Control

ABSTRACT

This module summarizes four major reasons for employing monitoring during design and operation of a land application site: documentation of existing water quality and system performance, confirmation of design parameters, provision of data for future designs and for management decisions. Monitoring requirements are examined for different land treatment options--overland flow sites and others employing collection of surface runoff, underdrained sites, rapid infiltration sites with recovery wells, and downslope emergence of treated effluent from irrigation sites. Methods of taking water samples and soil moisture measurements are discussed. Wells, lysimeters, tensiometers, and piezometers are described in conjunction with this sampling. Monitoring of parameters other than water is discussed briefly. A very brief summary of governmental regulations pertaining to monitoring is included. (Author/BB)

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Land Application of Wastes

An Educational Program

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MONITORING AT LAND APPLICATION SITES

Module 18

January, 1978

SE 025 032

LAND APPLICATION
OF WASTES -
AN EDUCATIONAL PROGRAM

The objective of this program is to increase the knowledge of engineers, scientists, waste management specialists and other practitioners in the concepts and principles needed to properly utilize the potential of land for the application of wastes. It is designed for individuals concerned with waste disposal alternatives for municipal, industrial, and agricultural wastes. The modules in this Program incorporate knowledge from sanitary and environmental engineering, agronomy, soil science, agricultural engineering, economics, and law.

The program consists of some twenty-five modules and audio-visual materials as appropriate.

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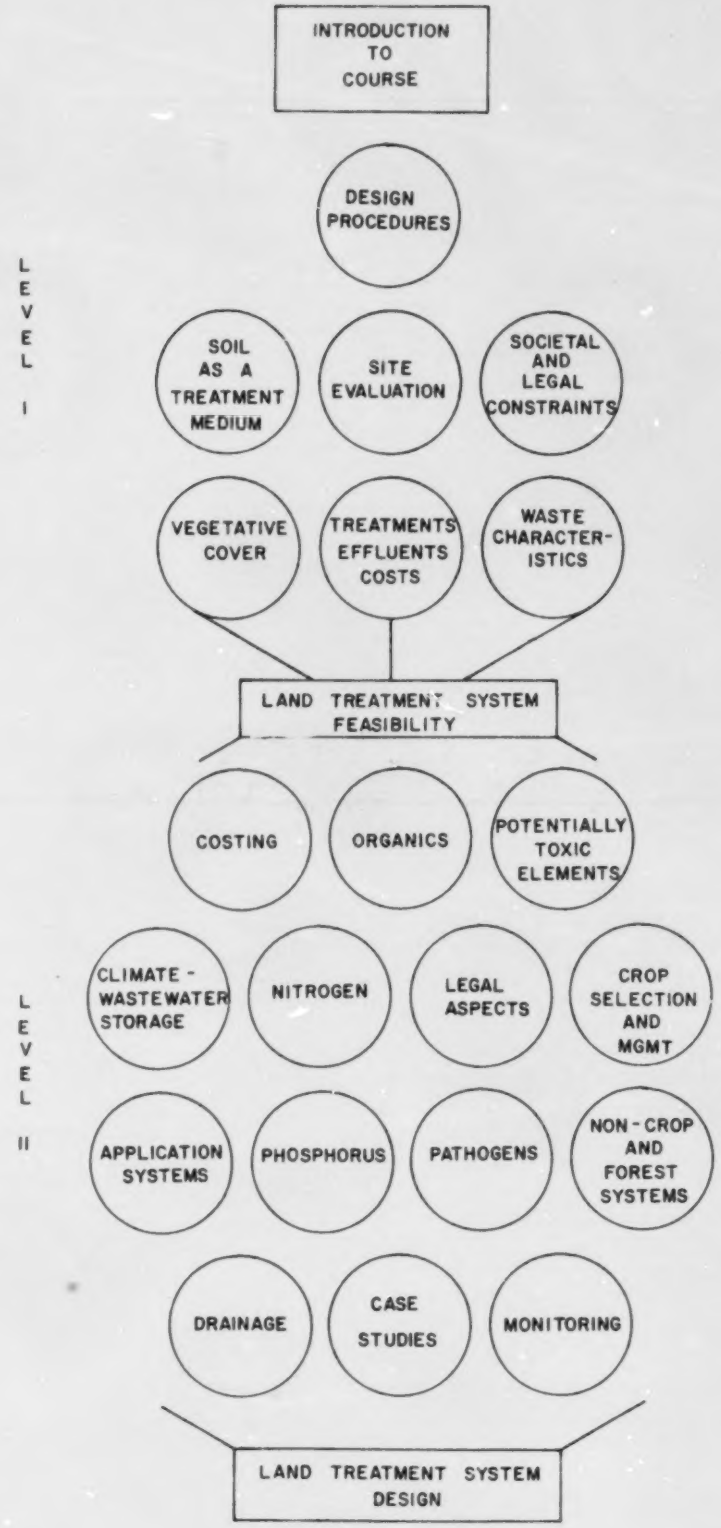

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MONITORING AT LAND APPLICATION SITES

Module 18

January, 1978

Summary

This module summarizes four major reasons for employing monitoring during design and operation of a land application site: documentation of existing water quality and system performance, confirmation of design parameters, provision of data for future designs and for managment decisions. Monitoring requirements are examined for different land treatment options--overland flow sites and others employing collection of surface runoff, underdrained sites, rapid infiltration sites with recovery wells, and downslope emergence of treated effluent from irrigation sites

Methods of taking water samples and soil moisture measurements are discussed. Wells, lysimeters, tensiometers, and piezometers are described in conjunction with this sampling.

Monitoring of parameters other than water is discussed briefly. A very brief summary of governmental regulations pertaining to monitoring is included.

Table of Contents

	Page
Summary	i
List of Figures	iv
List of Tables	v
Glossary	vi
Objectives	vii
I. Introduction	1
A. Monitoring in Land Application	1
1. Documentation	1
2. Confirmation	1
3. Future design	1
4. Management decisions	2
B. Environmental Quality	2
II. Monitoring Water Treated by Land Application	5
A. Sampling for Water Quality	5
1. Surface Water	5
a. Case I-overland flow	5
b. Case II-underdrain	6
c. Case III-recovery wells	7
d. Case IV-natural emergence	7
e. Monitoring surface water	8
2. Subsurface Water	9
i. Saturated soil and the use of wells	10
a. The cost of wells	11
b. The placement of wells	11
c. A hydrogeologic assessment of the site	13
d. The layout of the monitoring field	13
e. Sampling from wells	16
f. Specific guidelines	16
ii. Unsaturated soil and lysimeter	16
a. Lysimeter cost	17
b. Advantages of lysimeters	17
c. Number of lysimeter clusters	18
B. Measuring Soil Moisture	18
1. Unsaturated soil and tensiometers	19
a. Tensiometer	19
b. Costs	20
c. Tensiometer fields	22
2. Unsaturated soil and piezometers	22

		Page
III.	Monitoring Parameters Other than Water	23
	A. Air Monitoring	23
	B. Soil Monitoring	24
	C. Monitoring Life Systems	24
	D. Aesthetic Appeal	26
	E. Influent Monitoring	26
IV.	Water Quality Criteria	27
	A. Federal Requirements	27
	1. Maximum contaminant levels for inorganic chemicals	29
	2. Maximum contamination levels for fluorides	29
	3. Maximum contaminant levels for organic chemicals	29
	4. Maximum contaminant levels for turbidity	29
	5. Maximum microbial contaminant levels	30
	6. Projected changes	30
	a. Sodium and sulfates	30
	b. PCB's and asbestos	30
	7. Groundwater monitoring protocol	30
	8. Irrigation water quality	32
	B. State Requirements	32
	Bibliography	34
	Appendix	36

List of Figures

Figure		Page
1.	Conventional treatment systems are well researched and the wastewater strength at each stage can be predicted.	4
2.	Land application systems have an inadequate backlog of empirical data needed for completely reliable predictions of performance.	4
3.	Water sprayed onto overland flow system is collected in a receiving trench or lagoon before discharge.	5
4.	Underdrains collect groundwater and return it to the surface.	6
5.	Recovery wells may bring treated water back to the surface for storage or discharge.	7
6.	Water emerges wherever the water table intersects the surface. It appears as springs, sloughs, bogs, swamps, or as recharge for local rivers.	8
7.	A drilled well extends below the water table and has several sanitation protection features to assure reliable sampling.	10
8.	The cost of monitoring wells increases with depth.	12
9.	A hypothetical monitoring field which is critiqued in the text.	14
10.	Groundwater flow may be expected to have a well defined, uniform flow (Fig. 10-A), but in fact, be determined by channeling in subsurface fracture zones (Fig. 10-B).	15
11.	A tension lysimeter pulls water from unsaturated soil through a porous cup to a collection flask.	17
12.	The force needed to move water from unsaturated soil is inversely related to the percent of soil moisture.	20
13.	Tensiometers are filled with water and the flow to the soil is related to soil moisture tension by a vacuum gauge.	21
14.	The recommended minimum monthly samples for coliform testings increase with the population served.	31

List of Tables

Table		Page
1	Maximum levels of nine inorganic chemicals (excluding fluoride) are stipulated for public water systems	28
2	Maximum fluoride levels are established based on the climate in which the public water system is located	28
3	Maximum levels of specific organic chemicals apply only to community water systems	29
4	The maximum concentrations of inorganic chemicals in irrigation waters are defined according to two standards	32

Glossary

bar - A unit of pressure equal to 10^5 pascals or 0.987 standard atmosphere.

methylene blue active substances - Surface active agents ("surfactants") contained in synthetic detergents, which produce a blue salt in the presence of methylene blue reagent.

PCB - Polychlorinated biphenyls, any of a number of organic compounds used in various industrial processes.

regolith - The blanket of unconsolidated rocky debris of any thickness that overlies bedrock and forms the surface of the land. Used in this sense to include the soil.

saturated soil - Soil in which all spaces, macropores and micropores, are filled with water. This condition is approached in the groundwater zone and sometimes above that after heavy rains or during irrigation.

soil moisture tension - The negative pressure which must be exerted on capillary water to extract it from a soil sample.

suction lysimeter - An instrument for obtaining samples of water percolating through soil.

tensiometer - A device to measure soil moisture tension, very similar to a lysimeter which is fitted with a pressure guage or manometer. Readings are made of the water tension developed in a porous cup at equilibrium with the surrounding soil moisture.

Objectives

On completion of this module, the reader should be able to do the following:

1. Diagram one instrument used for sampling soil moisture in unsaturated soils and discuss its operation, costs, details of what is sampled, placement in a land application field, and usefulness as a monitoring device.
2. Discuss the three distinctions in groundwater made within the EPA guidelines and the implications each has for monitoring systems.
3. EPA drinking water quality guidelines specify maximum contaminant levels for inorganic and toxic organic compounds. List five inorganic and three toxic organic compounds included in those guidelines.
4. Discuss the relative response time of wells, lysimeters, and underdrainage and comment on advantages and disadvantages of each.
5. List and understand four reasons why monitoring is needed for waste treatment by land application.
6. List three parameters not connected with groundwater which might be monitored in at least some systems of land application.
7. Discuss the role monitoring plays in the management of land application systems.

Introduction

Monitoring Land Application Sites Serves Several Functions

Monitoring serves four distinct functions in land application systems:

1. Provides the documentation needed to prove that requirements of regulatory agencies are being met.
2. Confirms the adequacy of the original design.
3. Acts as source of data for future design.
4. Forms a basis for certain management decisions.

Monitoring provides data to prove that the land application system complies with standards of water quality and environmental safety.

Documentation: Federal and State regulatory agencies specify minimum standards of water quality and environmental safety which must be maintained during the operation of the land application system. Most of these are reviewed in this module and analytical techniques are given in APHA, et al., (1975). The collection and analysis of representative samples, either by the site management personnel or regulatory agencies, is needed to document compliance with the law. In order to fully document a site's performance, tests must be conducted prior to waste application in order to establish baseline characteristics.

Monitoring will reveal any inadequacies in the original design of the land application system.

Confirmation: Land application sites must be carefully designed so that the anticipated waste treatment comes as close as possible to actual achievements. In such a scheme, monitoring serves to confirm the adequacy of design. Although monitoring cannot be used to take the "bugs" out of an inadequate design, results will point out any inadequacies which can then be dealt with through operational changes or futher development of the system.

Future design: The present knowledge of land application systems is not as sophisticated as that of conventional treatment systems. For example,

using Figure 1 as a rough illustration, it is possible to predict the amount of a pollutant, say BOD, remaining in the wastewaters at various stages of a conventional treatment system. Unfortunately, such precise information is not available for land application systems as yet (Figure 2). While it can be determined what is applied to land, there is too much uncertainty to predict exactly what renovations are accomplished at various points as the wastewaters pass through land treatment. Therefore, good monitoring practice will provide more reliable data for the design of future systems.

Monitoring provides data which can be used in the design of future land application systems.

Management decisions: Modern land application systems are major improvements over old fashioned "sewage farms". Those "farms" used land as a simple waste sink and from them arose the horror stories of disease and pestilence, contaminated wells, and foul odors (Egeland, 1973). Furthermore, deleterious effects from old "sewage farms" were observed at considerable distances from the site and displaced in time from the actual act of waste discharge.

Monitoring provides information needed for careful day-to-day management of the land application system.

However, even an adequately designed land application system can produce groundwater pollution, vegetation kills, water logged soils, runoff and soil erosion if subjected to poor management (Parizek, 1973 and Miller et al., 1974). While a well designed and adequately maintained monitoring program cannot improve a poor site design, conscientious monitoring cam improve the performance of a good design by providing the information needed for day-to-day management.

Laws on Environmental Quality Are Limited

At present, statutory requirements on land application systems are generally limited to defining

surface and groundwater sampling procedures and minimum water quality standards. In that light, it is fitting that the bulk of this module consider those issues. However, it is appropriate also to consider other parameters related to the general environment that may be monitored. These will be considered at the end of the module, recognizing that while research is needed on the impact of waste material on wildlife, vegetation, insects, and so on, such efforts probably are out of place if viewed as a continuing monitoring need at all facilities (Blakeslee, 1973).

Most laws on monitoring land application systems are limited to specifying the surface and groundwater sampling procedures and the minimum standards for water quality.

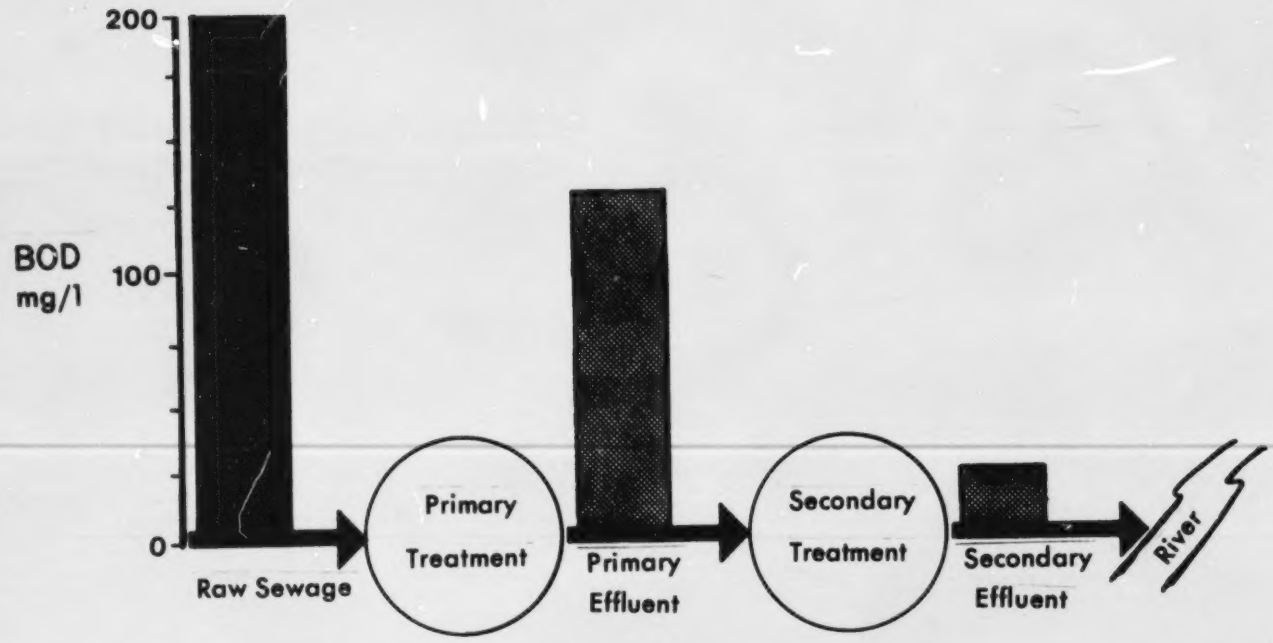


Figure 1
Conventional treatment systems are well researched and the amount of pollutant at each stage can be predetermined.

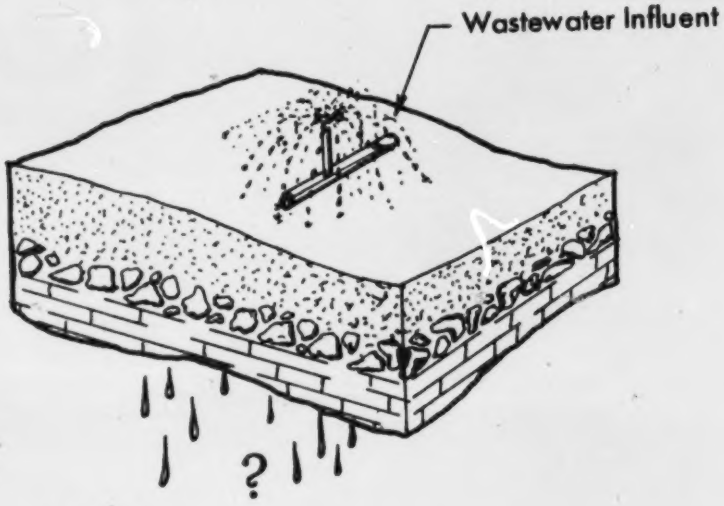


Figure 2
Land application systems have an inadequate backlog of empirical data needed for completely reliable predictions of performance.

Monitoring Water Treated by Land Application

Water treated by land application falls into two convenient categories:

1. Surface water: water that either remains on the surface or is returned to the surface.
2. Sub-surface water: water in unsaturated and saturated soils that does not emerge at any identifiable point.

Water treated by land application falls into two categories: surface and sub-surface water.

Each category offers distinct advantages and disadvantages regarding monitoring activities, so each will be discussed separately in this module.

Discharge of Surface Water Varies

When discussing surface waters, it is useful to identify four cases:

Case I-overland flow: An overland flow system is illustrated in Figure 3.

In overland flow systems, treated surface water collects in a surface channel prior to discharge or recycling through the system.

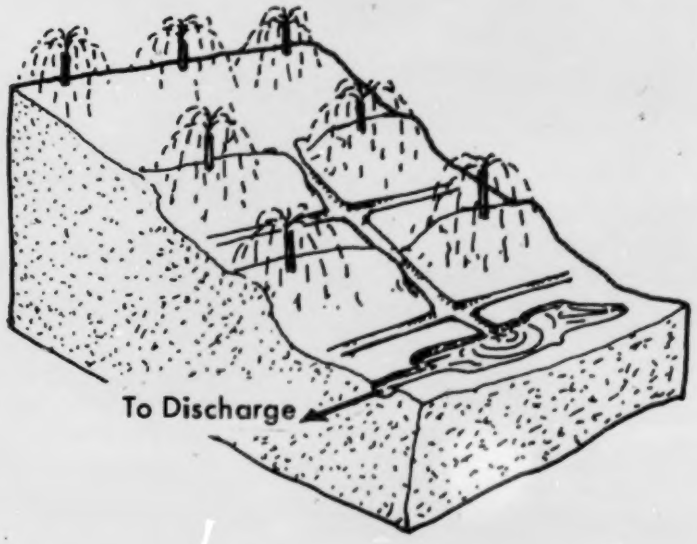


Figure 3
Case 1: Water sprayed onto overland flow system is collected in a receiving trench or lagoon before discharge.

Wastewater is applied onto a terraced hillside and allowed to collect, ultimately, in a surface channel prior to discharge. Even systems not specifically designed for overland flow often have dikes or ditches around the periphery to contain runoff from exceptional rainfall or snowmelt. Monitoring requirements of these systems will be no less stringent than conventional discharge systems. A discharge permit also will be necessary for these systems.

Case II-underdrain: Underdraining is common where water table levels rise close to the surface or where inflitration rates are to be improved, especially in less porous soils. A simple underdrain system is illustrated in Figure 4. Waters emerge from such systems as a point source discharge.

In an underdrained system, treated water emerges as a point source discharge.

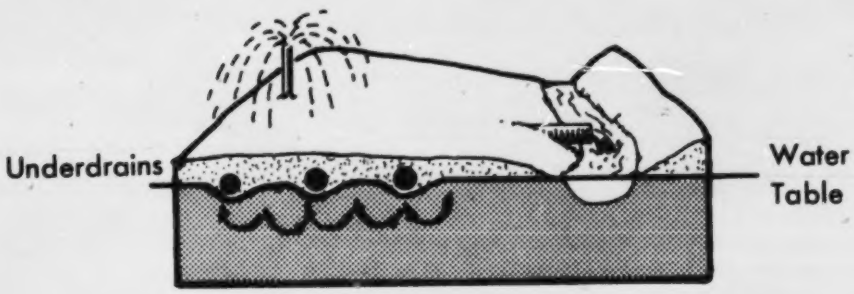


Figure 4
Case 2: Underdrains collect groundwater and return it to the surface.

Case III-recovery wells: Certain systems, such as the rapid infiltration system used by Flushing Meadows in Phoenix, Arizona (illustrated in Figure 5), seek to prevent contaminating natural groundwater by sinking recovery wells and pumping treated waters back to the surface. Like Case II, the outfall from such systems serves as a point source.

In rapid infiltration systems with recovery wells, water emerges as a point source discharge.

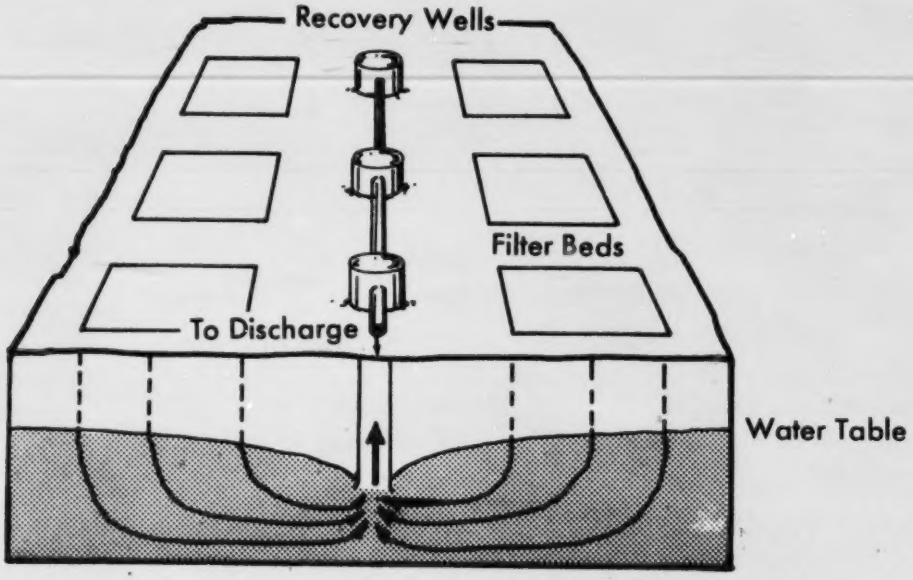


Figure 5
Case 3: Recovery wells may bring treated water back to the surface for storage or discharge (adapted from Stevens, 1974).

Case IV-natural emergence: In some instances, treated wastewater may emerge downslope from the application site. That occurs when the water table intersects the surface contour (illustrated in Figure 6). Unlike the three previous cases, the emergent water in this circumstance may represent only a small portion of the total wastewater flow and may or may not be representative of the bulk of groundwater quality.

Treated water emerges downslope from the application site if the water table intersects the land surface contour; this is a non-point discharge.

In the situation diagrammed in Figure 6, renovated

wastewater will emerge all along the river bank as a non-point source of river recharge water.

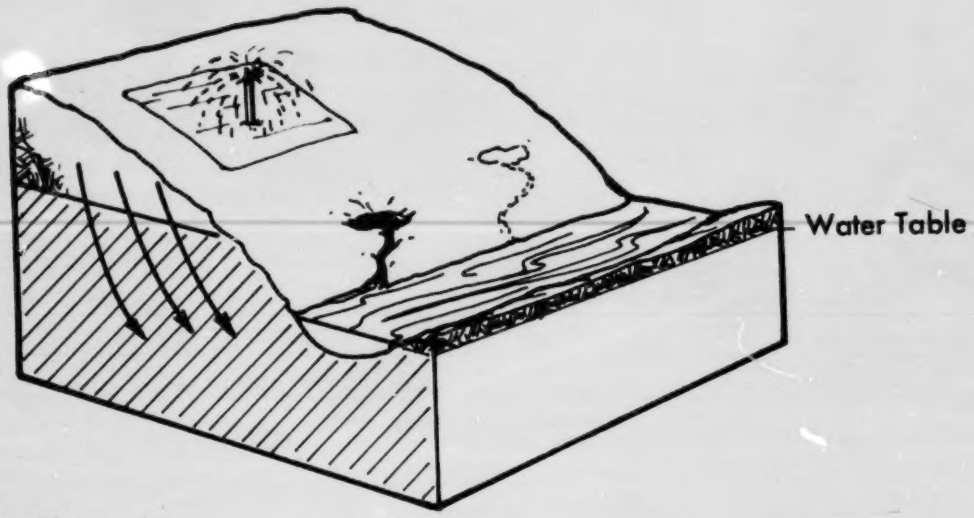


Figure 6
Case 4: Water emerges wherever the water table intersects the surface. It appears as springs, sloughs, bogs, swamps, or recharge for local rivers.

Monitoring of Surface Waters Must Meet Requirements

In cases I, II, and III noted earlier, the renovated wastewater is emerging from what is in effect a point source. Samples can be extracted with relative ease, analyzed, and recycled if necessary to assure adequate renovation.

If treated wastewater emerges from a point source it can be monitored easily to determine renovation efficiency.

In case IV, the emergent water quality may or may not represent the level of renovation that is occurring. Furthermore, there is little chance that these emergent waters can be recycled. Nevertheless, local surface waters which are likely to receive renovated wastewater need to be monitored regularly so that their water quality can be documented.

In all cases, a monitoring routine will have to be established in accordance with requirements set by local officials. Normally it can be expected that those requirements would specify sampling techniques and frequencies. Some of these should be similar to those used to sample outfalls from sewage treatment facilities or flows in natural surface waters. The water quality parameters which must be documented depend somewhat on the ultimate use of the water, but those discussions are reserved for the section on Water Quality Criteria (p. 27) of this module.

Treated wastewater emerging from point and non-point sources must be monitored according to the method and frequency specified by local officials.

Finally, it is extremely important to realize that even where water is discharged to surface waters, subsurface monitoring still may be very important. The Muskegon facility serves as a case in point. The renovated waters are discharged to Lake Michigan via one of two creeks, yet about 300 monitoring wells serve that site (Chaiken, et al., 1973).

Monitoring Subsurface Water Presents a Challenge

Subsurface water must be monitored but the question of how to obtain representative samples of groundwater for analysis is challenging. It is convenient to approach that problem by addressing two arbitrary categories of subsurface water:

Obtaining representative samples of groundwater for analysis to monitor the renovation efficiency of land treatment is often difficult.

1. Water of saturated soils sampled through the use of wells driven below the permanent water table
2. Water of unsaturated soils sampled through the use of suction lysimeters.

Saturated soil and the use of wells: A typical monitoring well, in place, is illustrated in Figure 7. Casings and other structures of such wells typically are made of plastics to avoid contaminating samples with products from corrosion within the wells itself. Further protection is provided by proper sealing procedures at the well head and using cement grouting

Water of saturated soils can be sampled through the use of wells driven below the permanent water table.

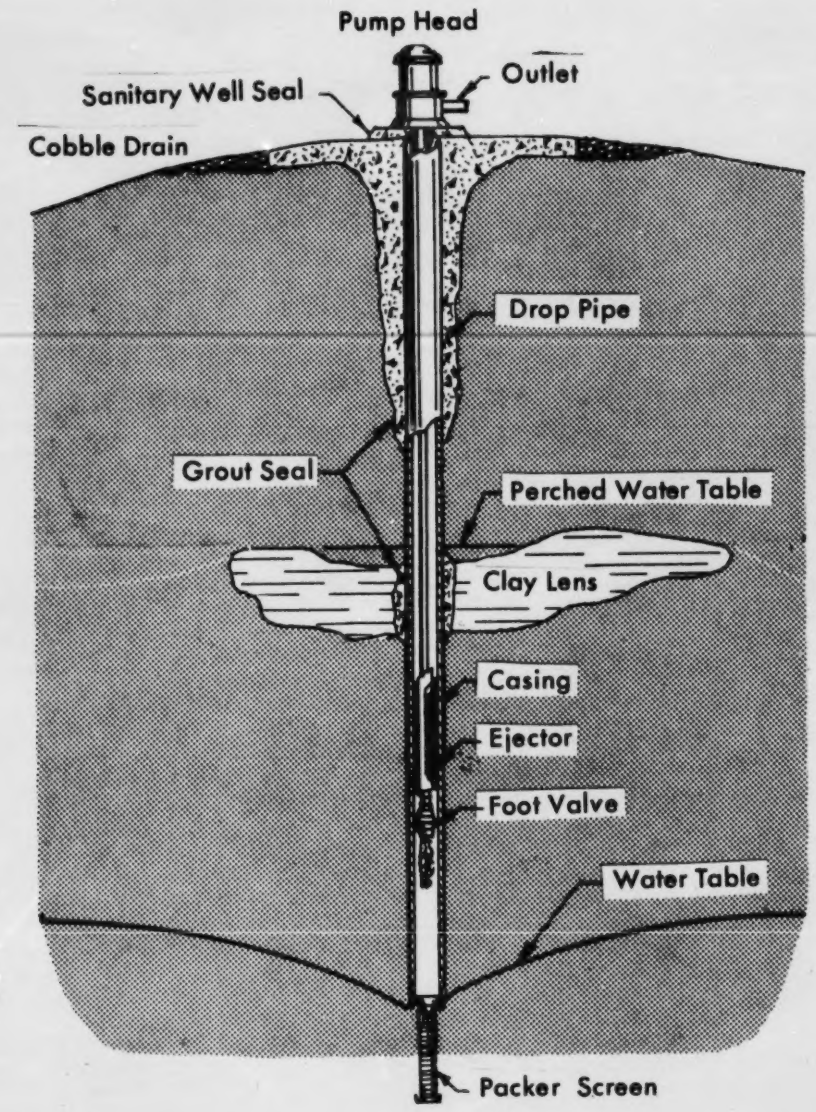


Figure 7
A drilled well extends below the water table and has several sanitation protection features to assure reliable sampling (adapted from U.S. EPA, 1975b).

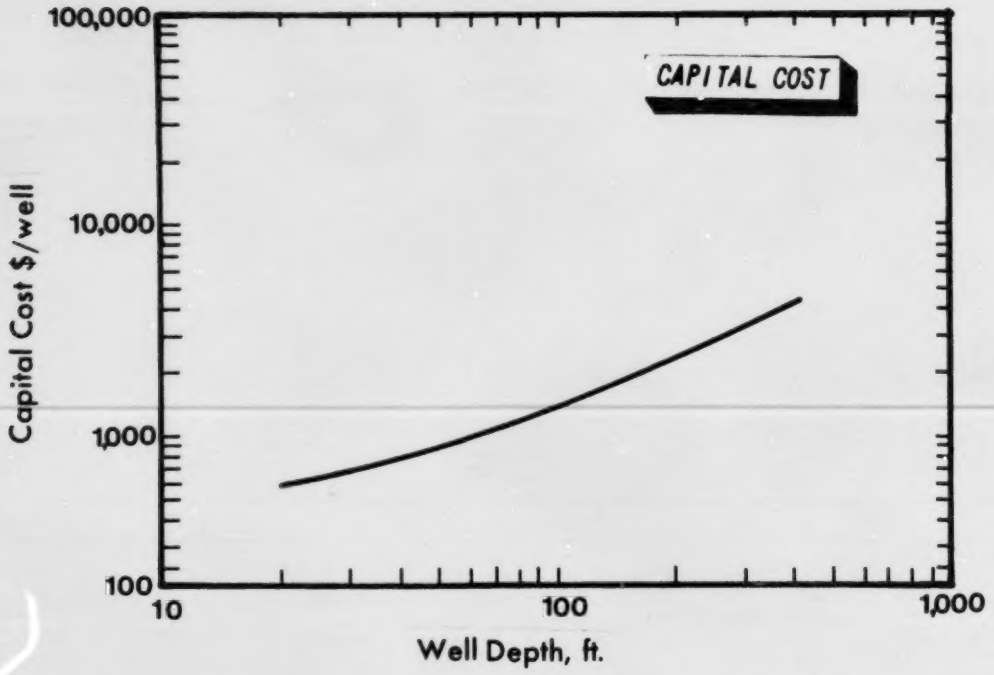
wherever necessary.

The cost of wells vary with depth. Approximate values, in 1975 dollars, are given in Figure 8. However, since monitoring wells often are not deep or required to penetrate thick layers of bedrock, their costs, relative to the development of the application site itself, are modest.

The placement of wells is, as yet (1977), not stipulated in any federal guidelines. Leadership in development of such guidelines has been taken by several states. The more conservative of these efforts recommend that wells be placed within and beyond the borders of the land application site and placed so that all subsurface waters flowing either into or out from the site can be sampled. Usually a single well in each direction of flow is adequate for small systems, but two and even three wells at the same distance and in a given direction gives information of greater statistical reliability. That precaution increases in importance in larger application systems as, for example, the Muskegon Project. At any rate, wells, or well clusters, are usually required to be no more than 250-500 feet apart at any given distance from the application site. The distance of points from each other and from the application area should depend on the permeability of the regolith. The higher the permeability, the greater the distance between wells. Also, it would be important to track the movement of groundwater with respect to time. If a pollution front was advancing, its position at some future date then could be predicted. That capability from a monitoring field would require more than one monitoring point up and down gradient from the site, and probably more than one depth of sampling. Other recommendations may stipulate that water be taken for analysis from neighboring private and public wells if contamina-

Precaution about the number and location of monitoring wells increases in larger land application systems; the Muskegon County system has 300 monitoring wells.

The distance between wells and from the application site to the wells should depend on the permeability of the regolith.



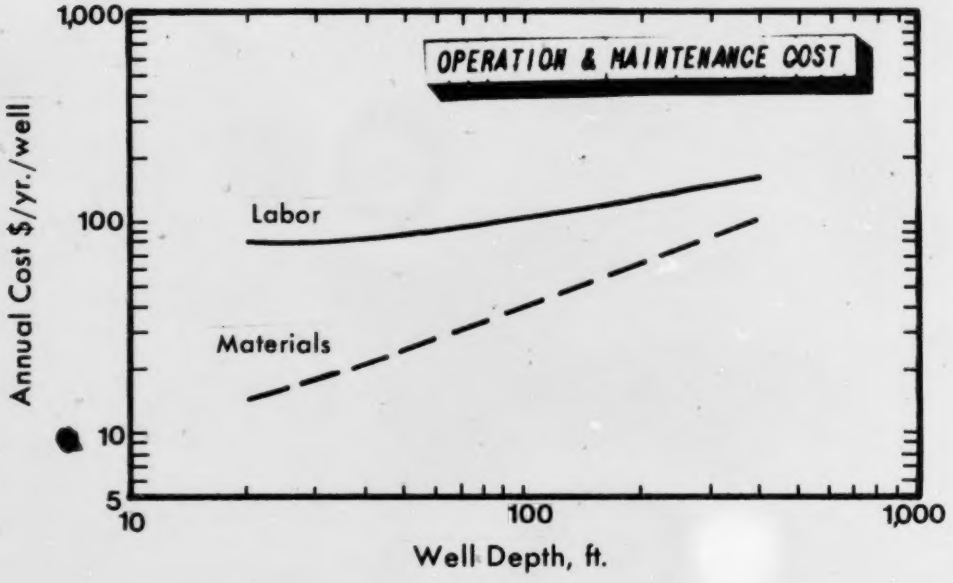


Figure 8: The cost of monitoring wells increases with depth (adapted from Pound, et al., 1975)

tion is a possible danger.

A hydrogeologic assessment of the site and its surroundings must be completed early in the design stages. That assessment should be done by a competent, experienced field consultant who can employ geologic maps, aerial photography, soil maps, seismic tests, borings, and physical geology. The coefficient of soil permeability needs to be determined (preferably using field methods). The usual test pit method, however, relying as it does on a steady state hydraulic head may be inadequate here (Pound and Crites, 1973). More expensive methods are sometimes necessary.

An experienced field consultant should do a hydrogeologic assessment of the site early in its design to determine the direction and rate of flow of groundwater both into and away from the site.

The purpose of these studies is to determine the direction and rate of flow of groundwater both into and away from a land application site. The direction of groundwater flow depends on subsurface soil conditions and does not always approximate topographic relief. Channels and fractures may alter flow rates and affect the direction of flow of renovated water. However, even after the hydrogeology of the site is approximated, the actual flow of water through saturated soils must be confirmed by test borings and analytical studies well in advance of the actual wastewater application.

The layout of the monitoring field can be planned once the hydrogeologic assessment is completed. In general, the field will have four subdivisions:

The layout of the monitoring field can be planned after the hydrogeologic assessment of the site.

1. "Up-gradient:" to provide baseline data on groundwater moving into the land application area
2. "Contact zone:" to provide data for the evaluation of events occurring both above and at the point of mixing of the renovated water and the natural groundwater
3. "Down gradient:" to evaluate the quality of subsurface water moving off-site
4. "Special locations:" to cover, if and when

needed, locations where inadequately treated wastewaters may present unusual hazards

A simplified hypothetical monitoring field with some built in errors is illustrated in Figure 9.

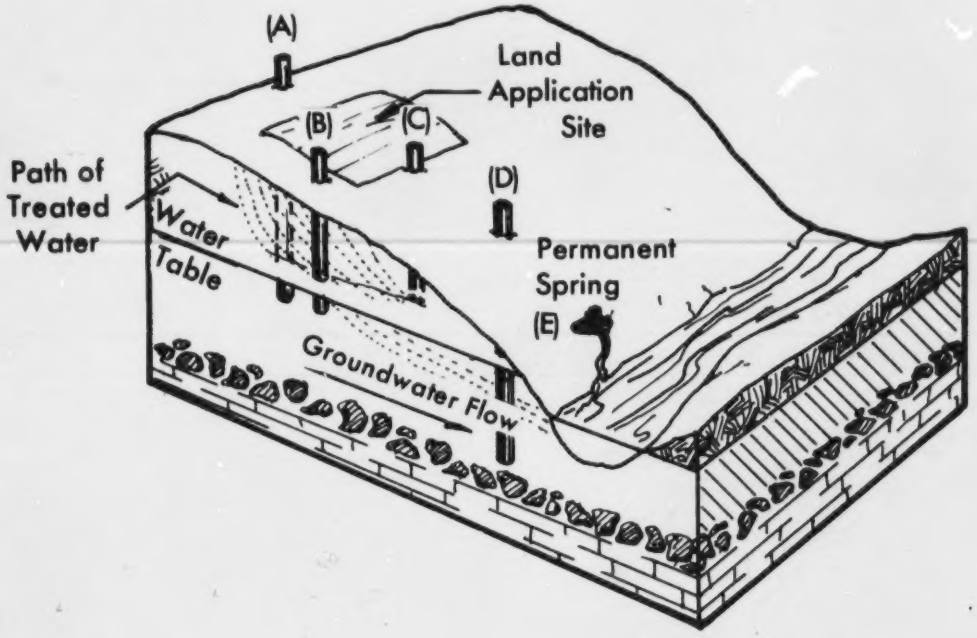


Figure 9
A hypothetical monitoring field which is critiqued in the text.

Notice that well (A) is situated to sample native groundwater flowing into the vicinity of the application field. Well (B) is poorly sited off to one side of the groundwater flow. Often it is very difficult to be sure that the well is sampling the effluent stream. Well (C) is properly sited, extending about 5 ft below the permanent water table and within the mixing zone for natural groundwater and renovated water. Well (D) may provide some interesting information on background quality of the groundwater, but would not be representative of effluent effects from the land application site. The problem here is that well (D) is too deep--almost to bedrock. Both the permanent spring (E) and the river receive renovated water. Clearly an effort must be made

to monitor these points.

Other possible flows may exist. For example, in Figure 10, two aerial views of the same application site are presented. It is assumed that most evidence suggests that subsurface flow will go as pictured in Figure 10-A and that wells could be placed as indicated. Yet if there are undetected features such as, say, the fracture zones mapped out in Figure 10-B, wastewater may be channeled undetected off-site with little renovation. Alternately, a fracture zone may bring large

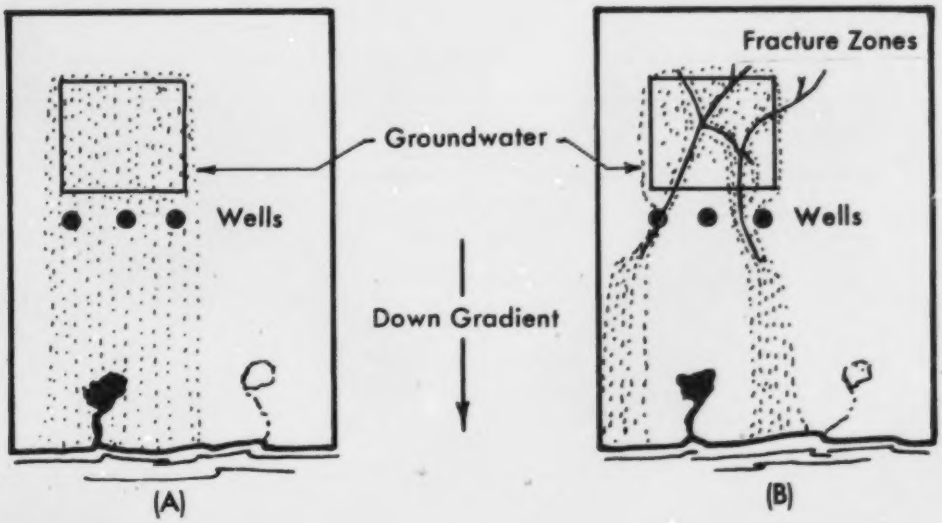


Figure 10
Groundwater flow may be expected to have a well defined, uniform flow (Fig. 10-A), but, in fact, be determined by channeling in subsurface fracture zones (Fig. 10-B). (adapted from Parizek, 1973)

volumes of high quality native groundwater into the application area, diluting the wastewater and leading to overly optimistic monitoring data (Parizek, 1973). Of course, if the site is located where potential underground channels exist, the problem of sampling renovated wastewater are compounded. This is a good example of the value of a hydrogeologic assessment in the planning stages of a land treatment system.

Subsurface fracture zones can alter normal groundwater movement and complicate the monitoring of groundwater.

Sampling from wells can be a source of error. For example, surface mounted suction pumps artifically decrease dissolved gases and volatile substances, and tend to leave solids behind. Where practical, submersible, corrosion resistant pumps should be used to draw water samples. Even hand bailing could be used in certain circumstances, but that may lead to the collection of "old" water which does not represent actual conditions (Parizek, 1973).

Another point to emphasize is that wells often have a very long response time. For example, Parizek (1973) reports more than than thirteen months were required for chloride ion to be detected in a 33 ft (10 m) well below the land application site at Penn State. Some 24 months passed before chloride ion began to be detected in concentrations above background in a well 275 ft (83 m) deep. Since chloride ion is not adsorbed into the soil and is considered a convenient "tracer" ion, it is apparent that in at least some cases well sampling may be several months, or even years, late in supplying information about renovation.

A set of specific guidelines for well monitoring fields has been given by Blakeslee (1973) and are reproduced in the Appendix.

Unsaturated soil and the lysimeter: Unsaturated soils hold moisture, but that water does not flow rapidly into wells or down gradient unless displaced by further additions. On the other hand, vegetation can exert a tension on that moisture. pulling it away from soil particles and into the roots. To sample this water, it is necessary to use an instrument called the suction lysimeter which uses a vacuum to pull water away from the soil. One form of such a lysimeter is illustrated in Figure 11.

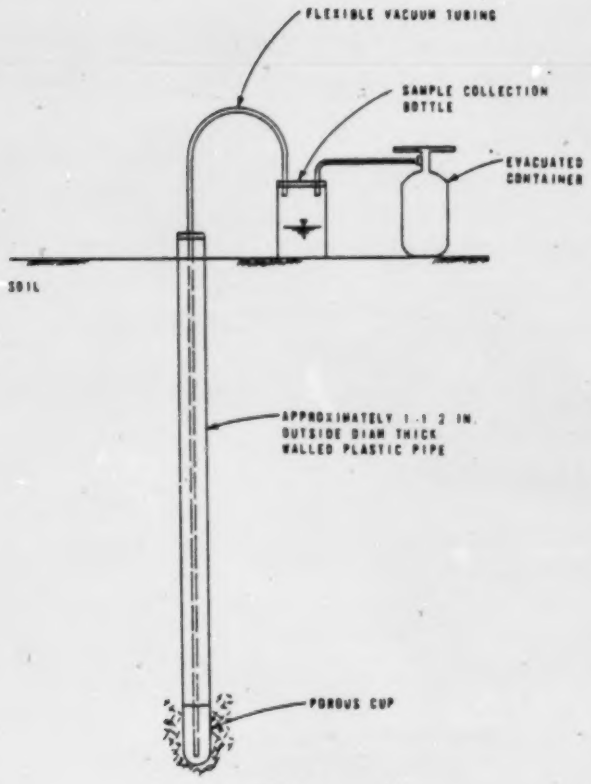


Figure 11. A suction lysimeter pulls available water from unsaturated soil through a porous cup and into a collection flask. (Pound and Crites, 1973).

These lysimeters cost around $12.00 each (4 ft. complete, 1975 prices) and are easily installed. The cost for such devices lies in the labor required to extract samples and in the laboratory analyses of the extracted water. Like wells, a cluster of lysimeters at a given sampling point provides greater statistical support for the data. In all likelihood, lysimeters would be more useful in spray irrigation fields than in overland flow or, particularly, rapid infiltration fields.

The advantages of lysimeters are that they provide means of obtaining rapid information on the quality of water before it reaches the water table. Since the major

portion of wastewater renovation occurs in the first few feet of soil, water samples taken by lysimeter can give information on impending PO_4^{-3}, NO_3^{-1}, and toxic substance breakthrough long before wells can. Lysimeters at various depths can provide the first indication of advancing fronts, give data that can help predict the rate of movement of contaminants, and allow early assessment of an impending exhaustion of soil C.E.C.

Lysimeters give rapid information on water quality before the wastewater reaches the groundwater, foretelling any undesirable breakthrough long before monitoring wells can.

The number of lysimeter clusters for a given site should be decided on the basis of what is needed to provide statistically acceptable information. Clusters must be protected from damage by machinery. One cluster for each spray field would not be unreasonable. Sampling schedules would have to be more frequent at first until the field behavior could be documented. Moving from weekly to bimonthly or longer schedules may be possible as monitoring data becomes available and is analyzed.

Land application sites developed for research purposes may use more elaborate lysimeters (e. g. pan lysimeters) and are more critical about lysimeter data (Hansen & Harris, 1975). Agronomic researchers should be consulted regarding the installation, costs, operations, and limitations of the various types of lysimeters (Parizek and Lane, 1970).

Measuring Soil Moisture Application schedules for wastewaters should reflect a realistic evaluation of actual soil moisture conditions. Climatic variations may require that application periods be shortened or even suspended temporarily: alternately, longer application periods may be acceptable during hot, dry periods. In any event, soil moisture must be evaluated to prevent soil waterlogging and to ensure that crop roots experience optimal moisture conditions. The most widely used methods of measuring soil moisture are electrical resistance cells, neutron scattering devices, and tensiometers. Electrical resistance is the

simplest method, but is not long-lasting or reliable. Accurate calibration is very difficult, and since the method relies on a block of gypsum which is dissolved by soil moisture, constant attention is required to maintain the units. Neutron scattering devices present exactly the opposite difficulty of being too sophisticated for most normal uses, although they could be considered for research applications or in irrigation projects when water application is to be minimized. These units bombard the surrounding soil with fast-moving neutrons which will be slowed only by hydrogen ions. The device incorporates a slow neutron detector to count reflected neutrons. This is an accurate method in mineral soils where water is the predominant source of combined hydrogen ions, but neutron scattering has some limitations in highly organic soils with other hydrogen ion sources. These devices are expensive.

A tensiometer is the most practical instrument to use to measure soil moisture at wastewater treatment sites.

Tensiometers are by far the most practical method for treatment site management applications.

The tensiometer uses the principle that water in the instrument will equilibrate with water in the surrounding soil, thus creating a suction in the tensiometer which will be equal to that in the soil. This pressure is read on a vacuum guage. The general principles are illustrated in Figure 12. As the percent of soil moisture (grams of water per 100 grams of soil) decreases, greater vacuum pressure is needed to extract the water. The tensiometer, then, is much like a lysimeter but is fitted with a pressure gauge. However, in practice the tensiometer is filled with water and the negative pressure (soil moisture tension) is developed as water flows from the porous cup to the soil. The sensitivity of the pressure gauge combined with the small total volume of water in the instrument allows a full scale deflection with the movement of only a few hundredths of a milliliter of water for some models. Figure 12 indicates that a typical tensiometer can read up to about 1 bar pressure, which would be a sufficient range for wastewater application sites. Their most useful range is between 0 and 0.8 bars, and they are applied successfully in monitoring irrigation sites where moisture levels are maintained near field capacity (Brady, 1974).

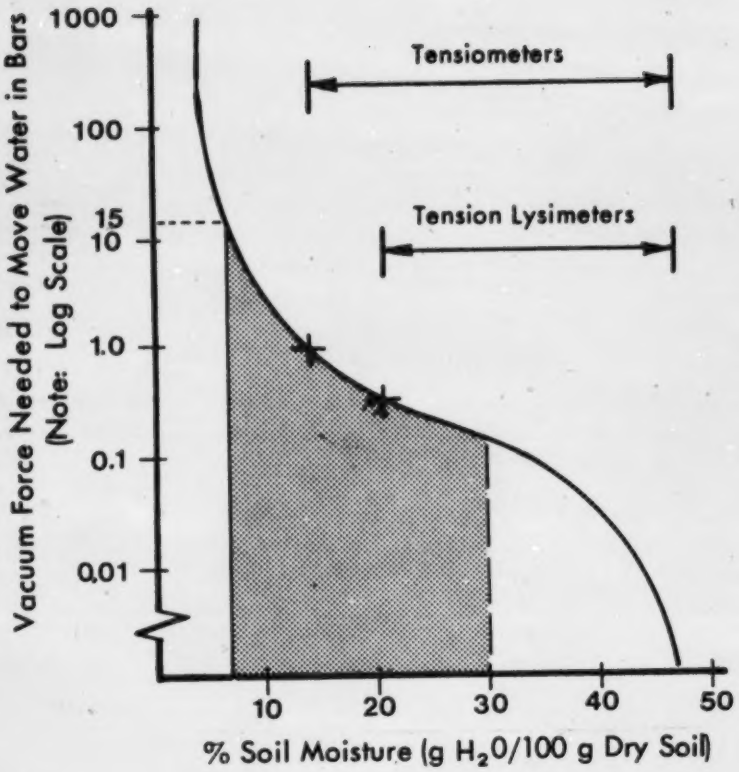


Figure 12
The force needed to move water from unsaturated soil is inversely related to the percent of soil moisture (adapted from Brady, 1974).

Costs of tensiometers vary with the length and complexity of the instrument, but in general are comparable to lysimeters. A 48" tensiometer similar to the one illustrated in Figure 13 was around $16.00 (1975 prices). A single probe with multiple tips, capable of measuring soil moisture tension at several depths simultaneously, costs around $165.00 (1975 prices).

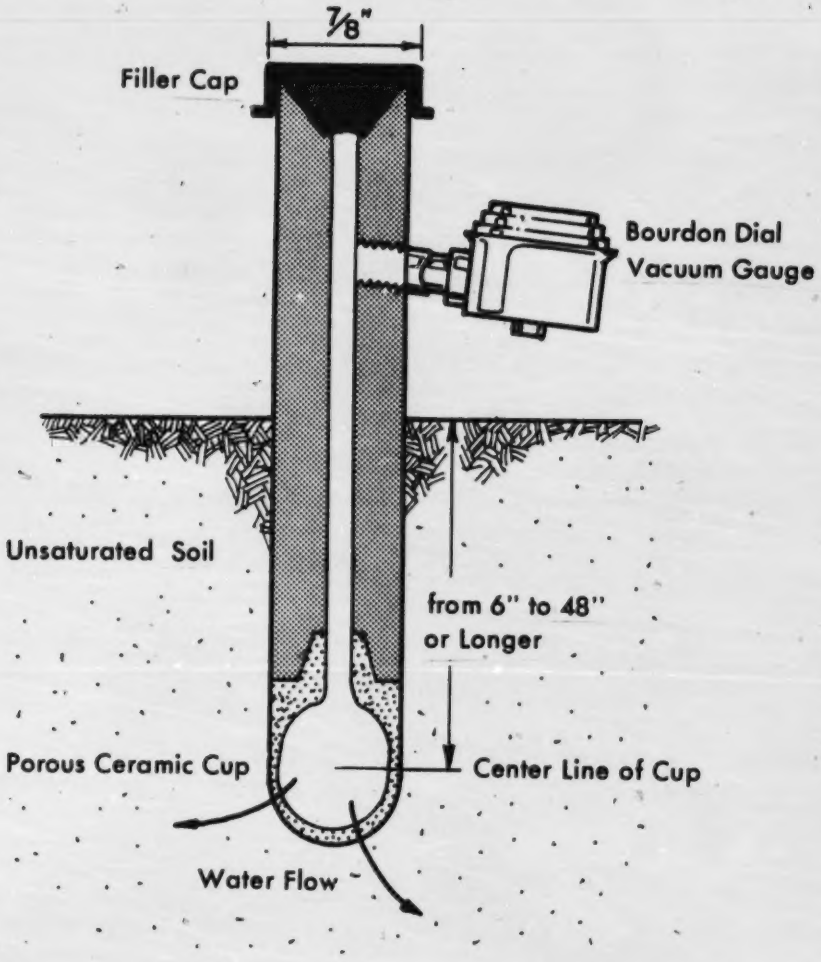


Figure 13
Tensiometers are filled with water and the flow to the soil is related to soil moisture tension by a vacuum guage (adapted from Soil Moisture Equipment Co., 1975).

Tensiometer fields need to be protected from mechanical injury of course, but do not have to be clustered. The number of tensiometers needed will be very site specific, and should be placed in such a way that the range of conditions on the site can be monitored. It may be useful to implace one tensiometer in each spot that may tend to become unusually dry and in one or two spots that can be expected to represent "average" soil conditions. Tensiometers are not difficult for one person to prepare and install.

The number of tensiometers is site specific; they should be placed so as to monitor the range of conditions on the site.

Unsaturated soil and the piezometer: A fourth instrument used to take measurements on soil moisture is the piezometer. The piezometer measures the relative pressure to which soil water is subjected at various depths. They may be used to examine subsurface flow to potential seep spots, to streams, swamps, and so forth. Piezometers may be employed in the initial stages of site assessment under the direction of competent soil scientists. Application sites designed for research purposes may employ piezometers. However, piezometers are not suitable for wet soils and are of little interest to the usual working application site.

Monitoring Parameters Other than Water

While water quality remains a major concern of monitoring programs, other environmental factors may be of greater or lesser concern to individual sites. It is not unreasonable to expect that at least some of these areas may come under state (if not federal) regulation in the future.

Air May be Monitored for Aerosols, Odors

Two distinct areas of possible air monitoring are aerosols and odors. Aerosols are tiny droplets of water, especially common to high pressure spray systems, and carried off-site by winds. Bacteria and viruses may be contained in aerosol droplets, and sampling and analysis of microorganisms require competencies beyond routine managerial skills or training.

Conditions at land treatment sites that may have to be monitored by law in the future are: the production of aerosols & odors, soil impact on living organisms, appearance of the site, and quality of influent.

Experience from other systems will be useful in designing and predicting the performance of new land application projects. Aerosol generation and monitoring is discussed at some length in Module 9, "Pathogens", including the results of monitoring studies which have been carried out.

Odors may be very hard to document or control. Land applications systems usually are odorless or, at worst, odorous only occasionally and then only mildly so. That is particularly true when the applied wastes are from secondary pretreatment. It may be decidedly false when applied wastes are of high organic content (such as cannery waste) or are sludges which are surface applied rather than incorporated into the soil.

What constitutes an objectionable odor is highly subjective. Large animal feed lots may smell terrible to the neighbors, but

may smell like money to the owner (so the saying goes). Nevertheless, when land application systems become waterlogged or suffer excessive loadings of putrescibles, malodorous conditions can be expected. Those conditions are usually correlated with an increase in incoming telephone calls as well as recognized by the site personnel, which obviates the need for sophisticated monitoring instrumentation.

Soil Should be Monitored Routinely

Soils should be subjected to routine, periodic analyses particularly if the community inventory and influent analyses indicate a significant loading of potentially toxic materials. The most important soil parameter in relation to uptake of metals and other waste constituents is the cation exchange capacity (CEC). The CEC of the site should be determined in the design stage as a factor in determining site area, then periodically after the site becomes operational to evaluate its remaining lifetime. Such analyses could occur on a semi-annual basis in most cases. Planting vegetation known to be particularly sensitive to suspected toxicants as a "poor man's" monitoring device can be very useful in eliminating the need for much more involved and costly laboratory analyses. The chemical analysis of soils is beyond the skills of most site managers and would be expected to be subcontracted to a competent analytical laboratory. Site managers need to know the rates of accumulation of toxic material and site degeneration, and the vertical distribution of toxic elements and phosphorus, as well as other soil changes.

Soil monitoring should include the rate of accumulation of toxic elements, site degeneration, and the vertical distribution of toxic elements and phosphorus.

Monitoring Plant and other Living Systems May Indicate Onset of Toxic Conditions

Land application systems have been called "living filters"

(Kardos, et al. 1973) because of their close connection with microbial populations, higher plants and higher animals. Nevertheless, the impact of waste application on living organisms is not routinely assessed except in research projects. There are many reasons for this.

The soil microflora is seldom monitored. Pathogens can exist in soils, but not proliferate, so monitoring them is not routine. Fecal coliform moving to the underlying water table is detected through well-water analyses, not soil analyses. Similarly, soil fungi and actinomycetes are not routinely monitored nor need they be.

Higher life forms are of more interest to the management of land application systems, although they also are not routinely monitored. Included in this category would be many of the worms, slugs, spiders, grubs, and insects that normally populate a healthy, well diversified soil community. The absence of such organisms from a site where they would normally be expected in profusion may be the first indication of the onset of toxic conditions.

The absence of life forms such as spiders, slugs, grubs, and insects from the land application site may be the first indication of the onset of toxic conditions.

Certainly it would be far more important to carefully monitor life systems where land application is being used to support specific life forms. For example, to develop a land application system for forests and then never establish a routine, however simple it may be, for assaying the health of that forest, would be quite irresponsible. Similarly, land application used to support crops should be surveyed in terms of the health of the crops and their suitability (viz. toxic element content) for consumption.

Here again it may be necessary to utilize the expertise of foresters, extension agents, or even knowledgeable farmers. Systems used for irrigating parks, golf courses, roadsides, spoils banks and so on should be routinely monitored (on a contractual basis if necessary) by experts in the respective areas.

Aesthetic Appeal May Be Needed for Public Acceptance

Since land application systems can be quite controversial, it may be necessary to invest in surface landscaping and ground maintenance to gain public acceptance. This may be particularly true for public facilities as sensitivities to environmental quality grow in the future. Also, some noncrop, recreational facilities using wastewater (viz. golf course [Sullivan, 1970]) are very vulnerable to criticisms if appearances deteriorate.

Influent Quality has Far-Reaching Effects

Throughout this module the assumption has been that the character of the influent used for land application has been ascertained through quantitative and qualitative analyses. Certainly that knowledge is needed in the very preliminary design stage. Since influent quality may change with time, it is necessary to maintain a regular schedule for influent analysis. Changes in influent quality may affect the functioning or even lifespan of a site. Influent to a land application site may be raw wastewater or effluent from conventional treatment processes. Characteristics of the various influent possibilities are discussed at length in Modules 4 and 5, "Treatment Systems, Effluent Qualities and Costs" and "Waste Characteristics".

Water Quality Criteria

Water quality criteria are established under federal law and, in some instances, further defined under state laws. Certain aspects of those requirements are reviewed in the following paragraphs.

Federal Requirements Apply to Groundwater

Federal requirements apply to "public water systems" as defined in the Public Health Service Act and amended by the Safe Drinking Water Act, PL 93-523 (Train, 1976). For administrative purposes, public water systems as defined by federal regulations are categorized as either "community water systems" or "non-community water systems". Furthermore, groundwater resulting from land application is arbitrarily divided into three cases:

Case 1: Groundwater which has the potential for being used as a drinking water supply.

Case 2: Groundwater which is used for drinking water supply.

Case 3: Groundwater which has either unpredictable uses or uses other than drinking water supply (Train, 1976).

Federal water quality requirements are the same whether groundwater is a potential or an actual source of drinking water. If the ground water is not used for drinking or if its future use is unknown, evaluation of such systems is on a site-by-site basis.

For the most part, those delineations were created to allow flexibility in special situations. The basic water quality requirements promulgated by EPA for drinking water sources, however, apply across the board except for Case 3 which requires a site-by-site evaluation. Also, where natural groundwater quality does not meet federal groundwater requirements, the criteria that apply are that no further deterioration in water quality can result from land application. The specific federal water quality criteria are given in the "National Interim Primary Drinking Water Regulations" (EPA, 1976), which went into effect in June of 1977 and are summarized below.

TABLE 1: Maximum levels of nine inorganic chemicals are stipulated for public water systems (EPA, 1976)

Contaminant	Level (mg/l)
Arsenic	0.05
Barium	1.0
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.0
Selenium	0.01
Silver	0.05

TABLE 2: Maximum fluoride levels are established based on the climate in which the public water system is located (EPA, 1976)

Temperature degrees Fahrenheit[1]	Degrees Celsius	Level (mg/l)
53.7 and below	12 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

[1]Annual average of the maximum daily air temperature

Maximum contaminant levels for inorganic chemicals: Specific maximum contaminant levels for inorganic chemicals are given in Table 1.

Maximum contamination levels for fluorides: A small margin separates beneficial levels of fluoride from levels which cause adverse effects. That fact prompted EPA to define maximum fluoride concentrations in terms of the climate served by the public water system as defined by the mean maximum daily air temperatures of the locality. The toxic effect of fluoride in drinking water is limited to mottling of dental enamel and minor changes in bone density, and there is evidence that these physiological effects are temperature dependent at various concentrations with small margins between beneficial and detrimental effects (Train, 1976).

Maximum contaminant levels for organic chemicals: The maximum contaminant levels of Table 3, applying only to public drinking water systems, are an adjunct to the "Special Monitoring Regulations for Organic Chemicals" (40 CFR Part 141, Subpart E) issued by the EPA. These regulations set out the tests to be performed and the procedures to be followed.

TABLE 3: Maximum levels of specific organic chemicals apply only to community water systems (EPA, 1976)

Organic Chemical	Maximum Level (mg/l)
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2, 4-D	0.1
2, 4, 5-TP Silvex	0.01

Maximum contaminant levels for turbidity: Samples for contaminant levels for turbidity in drinking water are taken at a representative entry point(s) to the drinking water distribution system. In effect, this requirement specifies that the monthly average may not exceed one turbidity unit. Certain exceptions are recognized, however.

Maximum microbial contaminant levels: Federal regulations specify microbial counts of coliform bacteria only. The actual number permitted per count depends on the technique used and on a monthly averaging formula. To avoid irregularities in arriving at average values, the minimum number of samples to be taken for coliform analysis per month has been established. That sampling routine is based on a sliding scale related to the population served as is given in Figure 14.

The coliform bacterium is the only microbe that the federal government regulates in its safe drinking water standards.

Projected changes: Further modifications of federal requirements are in the process of being enacted or may be expected in the near future. Some likely changes are reviewed below.

Sodium and sulfates are significant to diets of certain individuals and are discussed in the National Interim Primary Drinking Water Standards. Although it is recommended that the levels of these substances be made known so that certain persons susceptible to ill effects can be alerted to high concentrations, not enough evidence is thought to be available to promulgate standards.

Not enough evidence is yet available to create standards for levels of sodium and sulfates in drinking water.

PCB's and asbestos may be subjected to regulations when certain analytical methods, health effects, and environmental occurrence has been evaluated by EPA. Proposed rules were printed in the Federal Register of May 24, 1977.

Federal regulations on levels of PCB's and asbestos in drinking water have been proposed.

No federal guidelines have been issued (1977) on groundwater monitoring protocol pertaining to the kinds, number, or implacement techniques of groundwater monitoring devices to be used at land application sites.

The criteria for waters leaving land application

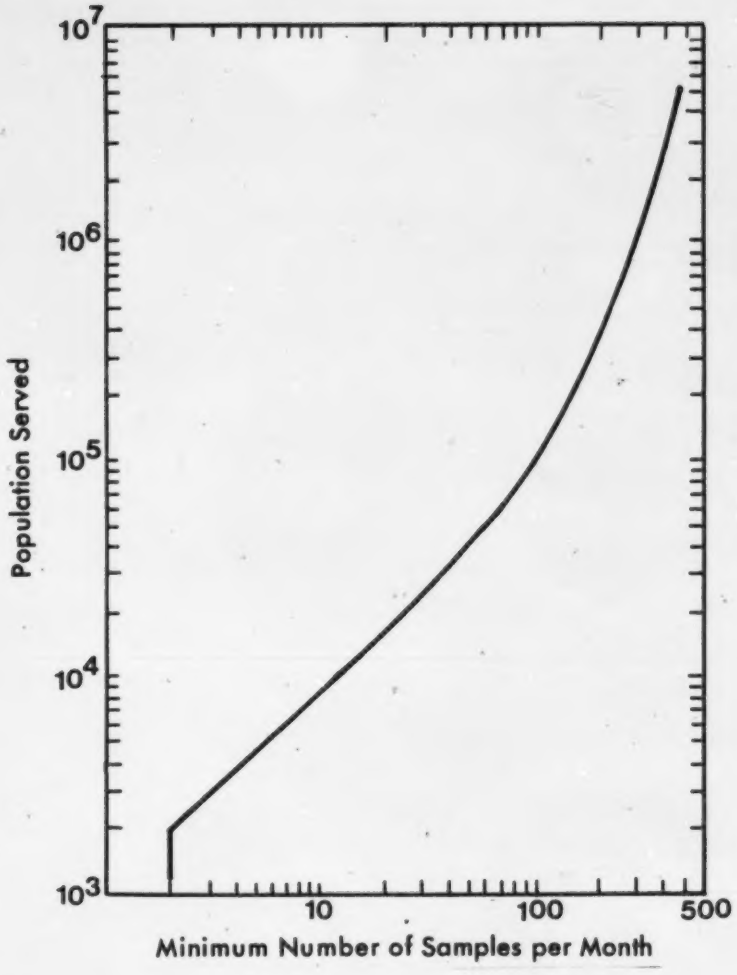


Figure 14
The recommended minimum monthly sample for coliform testing increases with the population served (adapted from U.S. EPA, 1975b).

sites has already been stated. But the following criteria for irrigation waters will usually apply to water being added to the land. The maximum permissible concentrations of inorganic chemicals in irrigation waters are given in Table 4.

Federal standards set the maximum permissible levels of inorganic chemicals in irrigation waters.

TABLE 4: The maximum concentrations of inorganic chemicals in irrigation waters are defined according to two standards (adapted from EPA, 1975a)

Substance	Max. Conc. Continuous Use, All Soils (mg/l)	Max. Conc. For 20 yr. Fine Textured Soil (pH 6.0-8.5) (mg/l)
Arsenic	0.10	2.0
Aluminum	5.0	20.0
Boron	0.75	2.0-10.0
Beryllium	0.10	0.50
Cadmium	0.01	0.05
Chromium	0.10	1.0
Cobalt	0.05	5.0
Copper	0.20	5.0
Lead	5.0	10.0
Manganese	0.20	10.0
Molybdenum	0.01	0.5
Nickel	0.20	2.0
Selenium	0.02	0.02
Zinc	2.0	10.0

State Requirements May be More Restrictive than Federal

State water quality regulations for public drinking water or irrigation water may be more, but not less, restrictive than federal requirements. Specific parameters that may be controlled include some or all of the following: chlorine residuals, BOD, pH, NH_3, dissolved oxygen, total hardness, methylene blue active substances, phenols, conductance, and chloride

State regulations on water may be more but not less restrictive than federal requirements.

ion.

Certain states specify minimum requirements for monitoring fields designed to sample groundwater related to land application fields while others issue non-obligatory "guidelines" (e.g. see Rhindress, 1973). The more conservative requirements specify that the groundwater at and around the proposed land treatment site be monitored for some time before start up to establish baseline data. Usually monitoring wells are required. Those wells must be placed where they can sample at several depths from the root zone to below the dry weather water table, sample in every direction of groundwater flow from a given site, and sample every direction from which natural groundwater may enter the site. Wells usually are to be located both within the site and off the site and no more than 250 to 500 ft.apart. Sampling from wells of neighbors may be required. Sampling schedules vary from before and after each application to once a month or once an application season. Often some allowance must be made for the frequent recording of water table levels. Land application designs which return renovated water to surface water through underdrains, high volume recovery wells, or overland flow to temporary storage, usually must sample the recovered water on a routine basis and allow for recycling, if necessary. Further discussion of some specific state guidelines, including monitoring requirements, can be found in Module 16, "Legal Aspects".

Some states require certain monitoring practices; others have non-obligatory guidelines for monitoring.

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Monitoring Considerations for Groundwater[1]

APPENDIX

Groundwater Monitoring Guidelines on Land Waste Disposal Facilities

Monitoring Objectives

The function of a groundwater monitoring program for proposed land disposal facilities is to confirm judgements made during design. This is to be accomplished by a continuing long-term in-depth hydrogeologic study regarding the performance of the system and its influence on surrounding groundwater conditions. This applies to:

1) Wastewater treatment lagoons
2) Wastewater storage lagoons
3) Land irrigation systems
4) Large subsurface disposal fields
5) Wastewater sludge disposal sites
6) Industrial waste concentrations disposal sites

At all such existing sites groundwater monitoring programs are needed to determine the influence of disposal practices on the groundwater resource.

Design of Monitoring Wells

Monitoring wells must be designed and located to meet the specific geologic and hydrologic conditions at each site. Consideration must be given to the following:

1) Geological soil and rock formations existing at the specific site.
2) Depth to an impervious layer.
3) Direction of flow of groundwater and anticipated rate of movement.

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[1] Blakeslee, 1973

4) Depth to seasonal high water table and an indication of seasonal variations in groundwater depth and direction of movement.
5) Nature, extent, and consequences of mounding of groundwater which can be anticipated to occur above the naturally occurring water table.
6) Location of nearby streams and swamps.
7) Potable and nonpotable water supply wells.
8) Other data as appropriate to the specific system design.

Groundwater quality should be monitored immediately below the water table surface near the application site as pollutional materials entering the groundwater system may have a tendency to remain in the upper few feet. Applied wastewater will generally be depressed within the groundwater system as the material travels away from the site. The need for sampling at more than one depth within a groundwater system will depend upon geologic conditions and distance from the pollutional source. Definition of the flow system with depth will be necessary to properly determine the depth to be monitored, especially when mounding is superimposed on the existing system.

Additional design and construction considerations are:

1) Monitoring wells in fine textured soils will require special construction such as gravel packing around the screen.
2) Wells constructed to a depth of 20' or more should be 4" in diameter to facilitate use of submersible pump equipment for sample collection unless alternative sampling methods are approved by the reviewing agency.
3) Construction should be by a registered well driller or contractor covered under Act 315, PA of 1969 using approved modern construction

methods.

4) Casings shall be grouted and capped and a cap-locking device provided. Use of a vented cap is desirable but care must be taken to prevent introduction of contaminants through such vents.
5) The well casing should be protected against accidental damage and adequately marked to be clearly visible during winter and summer conditions.
6) Each well should be labeled and identified (owner, owner's address, well number, use of well and warning).
7) If a monitoring well is to be permanently abandoned, approved procedures are to be followed.

Location

Groundwater monitoring wells must be located so as to detect any influence of wastewater application on the groundwater resource. A minimum of one groundwater monitoring well must be provided in each direction of groundwater movement near the pollutional source with adequate consideration being given to possible changes in groundwater flow due to mounding effects. The orientation and spacing of multiple wells shall be determined by conditions at each site.

Water Level Measurement

The following considerations apply with regard to water level measurement:

1) Water levels should be determined by methods giving precision to 1/8 inch or 0.01 feet. (Example - wetted tape method)
2) Measurements should be made from the top of the casing with the elevation of all casings in the monitoring wells system related to a permanent reference point, using USGS datum.

3) Water level measurements are to be made under static conditions prior to pumping for sample collection.
4) Monitoring wells should be installed early in the construction sequence and monthly water level readings obtained during the construction period and during the first two years of wastewater system operation to provide background information. Subsequent water level measurement frequency should be in accordance with a schedule established on a case by case basis.
5) All wells should be securely capped and locked when not in use.

Water Sampling

Background water quality: A minimum of three monthly samples should be collected from each monitoring well prior to placing the storage or disposal facility in operation. In cases where background water quality adjacent to the site may be influenced by prior waste applications, provision of monitoring wells or analysis of water quality from existing wells in the same aquifer beyond the area of influence will be necessary.

Operating Schedule: Samples should be collected monthly during the first two years of operation. After the accumulation of a minimum of two years of groundwater monitoring information, modification of the frequency of sampling may be considered upon written request.

Sample Collection

1) A measured amount of water equal to or greater than three times the amount of water in the well and/or gravel pack should be exhausted from the well before taking a sample for analysis. In the case of very low permea-

bility soils the well may have to be exhausted and allowed to refill before a sample is collected.

2) Pumping equipment shall be thoroughly rinsed before use in each monitoring well.
3) A pressure tank shall not be used with a sampling system since the water in the pressure tank would be particularly difficult to exhaust.
4) Water pumped from each monitoring well should be discharged to the ground surface away from the wells to avoid recycling of flow in high permeability soil areas, or soil erosion.
5) Samples must be collected, stored, and transported to the laboratory in a manner so as to avoid contamination or interference with subsequent analyses.

Sample Analysis

Water samples collected for background water quality should be analyzed for the following: (Note: Parameters for groundwater monitoring at industrial waste disposal sites must be established on an individual basis depending on the composition of the wastes applied).

1) Chloride
2) Specific conductance
3) pH
4) Total hardness
5) Alkalinity
6) a. Ammonia nitrogen
   b. Nitrate nitrogen
   c. Nitrite nitrogen
7) Total phosphorus
8) Methylene blue active substances
9) Chemical oxygen demand*

*Use of low concentration C.O.D. analysis methods per current edition of Standard Methods may be necessary.

10) Any heavy metals or toxic substances found in the applied wastes.

After adequate background water quality information has been obtained, a minimum of one sample per year, obtained at the end of the irrigation season in the case of seasonal operations, should be collected from each well and analyzed for the above constituents.

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Groundwater Monitoring System Reports

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ACKNOWLEDGEMENTS

The development of this program and the preparation of the modules resulted from the collaboration of many individuals in the College of Agriculture and Life Sciences, a statutory unit of the State University at Cornell University, and others. The primary faculty and staff associated with the project were:

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This program was supported in part by grant T-900500 from the Academic Training Section, U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers.

The current modules are based on modules developed during the initial phase of this project (1974-1976). Other personnel involved with writing or editing initial modules of the program included:

G. A. Garrigan, Education
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M. M. Bogin edited copy and contributed to written and audio-tutorial modules. S. M. Dabney was the primary author of the Crop Selection and Non-crop and Forest Systems modules.

J.K. Krizek, A.L. Liebermann and R.H. Nagell contributed art work and graphic design. L.A. Martin, A.C. Plescia, B.C. Littlefair and others provided secretarial assistance. D.P. Willmot prepared and processed audio-tutorial materials. Audio-tutorial program was narrated by K. Marash.

Other faculty assistance was provided by W.H. Allaway, D.R. Bouldin, D.J. Lathwell, G.W. Olson, and P.J. Zwerman. Technical assistance of various kinds was provided by R. Batkin, S. Haeni, W. Messner, D. Payne, D. Way, G. MacCaskill, and D. Krizek. Thanks are also due to many other members of the Cornell community who shared time, ideas, and materials.

Personnel of the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory, Hanover, N.H. and Office of the Chief of Engineers in Washington, D.C. reviewed the written and audio-tutorial modules. The audio-tutorial modules were also reviewed at the National Training and Operational Technological Center of the Environmental Protection Agency, Cincinnati, Ohio.

State environmental regulatory agencies provided land application guidelines. Many other individuals, companies, and federal agencies provided technical information, comments, and visual materials. Their generosity has made a major contribution to the program.

MONITORING AT LAND APPLICATION SITES

Objectives

Upon completion of this module, the participant should be able to:

1. Discuss the relative response time of wells, lysimeters, and underdrainage and comment on the advantages and disadvantages of each.

2. List and support three reasons why monitoring is needed for waste treatment by land application.

3. Indicate the limitations of wells as monitoring instruments.

4. Indicate why a hydrogeologic evaluation of a potential land treatment site is necessary from a monitoring point of view.

5. List three parameters not connected with groundwater which might be monitored in some land application systems.

6. List four places where groundwater ought to be monitored in a land application system.

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MONITORING AT LAND APPLICATION SITES

Module 18

January, 1978

MONITORING AT LAND APPLICATION SITES

This lesson concerns the reasons for the design of an acceptable monitoring system at a land treatment of waste site (Slide 1). The objectives for this lesson are located in the envelope that is in the lesson package. Find the envelope and take an objective list. Stop the tape recorder and study the objectives for this lesson (Slide 2). You may keep the objective list for reference during the lesson.

Monitoring serves four distinct functions in land application systems; these are indicated in Slide 3. The first three functions - the documentation, design adequacy, and management data functions are the most important from a practical point of view.

Slide 4 indicates drainage or leachate parameters that might be monitored to document that the treatment meets federal or state requirements. Collection and analysis of representative samples, either by the site management personnel or regulatory agencies is needed to document compliance with the law.

Land application sites must be carefully designed so that the actual achievements are equal or better than the design estimates. To fully document a site's performance, the characteristics indicated in Slide 5 ought to be measured prior to waste application in order to establish baseline characteristics. Even after startup of the site these characteristics should be monitored so that any change in influent can be noted and appropriate adjustments made.

Modern land application systems are major improvements over old fashioned sewage farms. Those farms usually used land as a sample waste sink and from them arose horror stories of disease, contaminated wells and foul odors. With poor management even a well designed land application system can result in sewage farm conditions. Slide 6 indicates other aspects of a land treatment site that could be monitored in order to make management decisions that work toward maximizing economic return and maintaining the site as a productive and efficient waste treatment area.

The present knowledge of land application systems is not as precise as that of conventional treatment systems. For example, as shown in Slide 7, it is possible to predict the amount of a pollutant, say BOD, remaining in the wastewaters at various stages of treatment. Unfortunately, such precise information is not available for land application systems as yet. This lack

of knowledge is illustrated in Slide 8. While it can be determined what is applied to land, it is difficult to predict exactly what renovations are accomplished as the wastewaters pass through land treatment. The information from monitoring the influent and the leachate plus the additional monitoring suggested in Slide 9, will help provide more reliable data for the design of future systems.

Since statuatory requirements binding on land application systems are generally limited to defining surface and groundwater sampling procedures and minimum water quality standards, the bulk of this lesson considers those issues (Slide 10).

The parameters that were mentioned earlier that do not directly relate to these regulations but can provide information concerning the general environment will be considered towards the end of the lesson. These parameters will probably not be a continuing monitoring need at all facilities, but will help research the impact of waste material on wildlife, vegetation, insects and so on and thus would be an appropriate monitoring function for the land application facilities that have the necessary personnel and money.

As indicated in Slide 11, water treated by land application falls into two convenient categories:

1. Surface water: water that either remains on the surface or is returned to the surface.
2. Sub-surface water: water in saturated and unsaturated soils that does not emerge at any identifiable point.

Each category offers distinct advantages and disadvantages regarding monitoring activities, so each will be discussed separately in this lesson.

In the case of surface water it is useful to identify four different types or cases of surface collections and discharge.

Case one - overland flow: An overland flow system similar to that used by the Campbell Soup Company at Paris, Texas is illustrated in Slide 12. In this case, wastewater is sprayed onto a terraced hillside and allowed to collect, ultimately, in a surface channel prior to discharge. Even systems not specifically designed for overland flow often have dikes or ditches around the periphery to contain runoff from exceptional rainfall or snowmelt. Monitoring requirements of these systems will be no less stringent than conventional discharge systems. A discharge permit also will be necessary for these systems.

Case two - underdrain system: Underdrains are common where water table levels rise close to the surface or where infiltration rates are to be improved, especially is less porous soils. A simple underdrain system is illustrated in Slide 13. Waters emerge from such systems as a point source discharge.

Case three - recovery well system: Certain systems such as the rapid infiltration system used by Flushing Meadows in Phoenix, Arizona, illustrated in Slide 14, seek to prevent contaminating natural groundwater by sinking recovery wells and pumping treated waters back to the surface. Like the underdrain system, the outfall from a recovery well system serves as a point source for discharge or reuse.

Case four - treated wastewater emerges downslope from an application site: This can occur when the water table intersects the surface contour as illustrated in Slide 15. Unlike the three previous cases, the emergent water in this circumstance may represent only a small portion of the total wastewater flow and may not be representative of the bulk of groundwater quality.

In the situation diagrammed in Slide 15, renovated wastewater may emerge all along the river bank as a non-point source of river recharge water.

Monitoring surface waters: In cases 1, 2, and 3, the renovated wastewater is emerging from what is in effect, a point source. Samples can be extracted with relative ease, analyzed, and recycled if necessary to assure adequate renovation (Slide 16).

In case 4, the emergent water may or may not present a good representation of the renovation occurring. Furthermore, there is little chance that emergent waters can be recycled. Nevertheless, local surface waters which are likely to receive renovated wastewater need to be monitored regularly so that their water quality can be documented.

In all cases, a monitoring routine will have to be established in accordance with requirements set by local officials (Slide 17). Normally it can be expected that those requirements would specify sampling techniques and frequencies. Some of these should be similar to those used to sample outfall from sewage treatment facilities or flows in natural surface waters. The water quality parameters which must be documented depend somewhat on the ultimate use of the water. These are discussed in the section on Water Quality Criteria later in this lesson.

Finally, it is extremely important to realize that even where water is discharged to surface waters, subsurface monitoring still may be very important. The Muskegon facility serves as a case in point. The renovated waters are discharged to Lake Michigan via one of two creeks, yet there are many groundwater sampling points as indicated in Slide 18.

In the four cases presented above, both surface water and subsurface water monitoring is required. With these systems and systems in which there is no surface discharge there are two arbitrary categories of subsurface water which might be considered for monitoring. These two categories, illustrated in Slide 19 are:

a) water of saturated soils sampled through the use of wells driven below the permanent water table.

b) water of unsaturated soils sampled through the use of suction lysimeters and tensiometers.

Saturated soil and the use of wells: A typical monitoring well, in place, is illustrated in Slide 20. Casings and other structures of such wells typically are made of plastics to avoid contaminating samples with products from corrosion within the well itself. Further protection is provided by proper sealing procedures at the well head and using cement grouting where necessary.

The costs of wells vary with depth. Approximate values, in 1975 dollars, are given in Slide 21. However, since monitoring wells often are not deep or required to penetrate thick layers of bedrock, their costs relative to the development of the application site itself, are modest.

A hydrogeologic assessment of the site and its surroundings must be completed early in the design stages. That assessment should be done by a competent, experienced field consultant who can employ geologic maps, aerial photography, soil maps, seismic tests, borings and physical geology (Slide 22).

The purpose of these elaborate studies is to determine the direction and rate of flow of groundwater both into and away from the land application site. The more conservative guidelines for the placement of wells indicate that wells be placed so that all the subsurface waters flowing either into or out from the site can be sampled. For small systems, a single well in either direction of flow is adequate. This is illustrated in Slide 23. Two and three wells in the same direction and at the same distance gives evidence of greater statistical reliability (Slide 24). A situation that from the

surface appears to indicate groundwater flow as in Slide 24, might actually have a flow like in Slide 25, depending upon subsurface conditions, channels, and fractures. Some of the wastewater could be diluted with native groundwater, some might be channeled off site with little renovation. All of these situations would lead to misinformation about the renovation taking place if the monitoring system were set up as in Slide 25. Even after the hydrogeology of the site is approximated, the actual flow of water through saturated soil must be confirmed by test borings and analytical studies in advance of actual wastewater application.

The layout of the monitoring field can be planned once the hydrogeologic assessment is completed. In general, the field will have four subdivisions illustrated in Slide 26.

1) "Up-gradient:" to provide baseline data on groundwater moving into the land application area.
2) "Contact zone:" to provide data for the evaluation of events occurring both above and near the point of mixing of the renovated water and the natural groundwater.
3) "Down gradient:" to evaluate the quality of subsurface water moving off-site.
4) "Special locations:" to cover, if and when needed, locations where inadequately treated wastewaters may present unusual hazards such as at the residence well in the slide.

A simplified hypothetical monitoring field, for the system in Slide 26, is illustrated in Slide 27. This example contains some built in errors for illustrative purposes.

Notice that well (A) is situated to sample native groundwater flowing into the vicinity of the application field. Well (B) is poorly sited off to one side of the groundwater flow. Often it is very difficult to be sure that the well is sampling the effluent stream. Well (C) is properly sited, extending about 5 feet below the permanent water table and within the mixing zone for natural groundwater and renovated water. Well (D) may provide some interesting information on background quality of the groundwater, but would not be representative of effluent effects from the land application site. The problem here is that well (D) is too deep - almost to bedrock. Both the permanent spring (and the river receive renovated water. Clearly an effort must be made to monitor these points. The well at the residence, (F), would have to be monitored and considered one of the special locations.

There is a booklet located in the box in which this lesson came. This booklet is titled "Booklet to Accompany the A-T, Monitoring at Land Application Sites" (Slide 28). This booklet contains an article by Blakeslee that summarizes monitoring considerations in relation to groundwater below the water table. Turn off the tape recorder and study the booklet. When you have finished, resume this lesson (Slide 29).

The water in unsaturated soil (Slide 30) does not flow rapidly into wells or down gradient unless displaced by further additions. On the other hand, vegetation can exert a tension on that moisture, pulling it away from soil particles and into the roots. To sample this water, it is necessary to use an instrument called the tension lysimeter which uses a vacuum to pull water away from the soil. One form of such a lysimeter is illustrated in Slide 31.

These lysimeters are inexpensive and easily installed. The costs for such devices lie in the labor required to extract samples and in the laboratory analysis of the extracted water (Slide 32). A cluster of lysimeters at a given sampling point provides greater statistical support for the data. Lysimeters are more useful with spray irrigation systems than in overland flow or, particularly, rapid infiltration systems.

The advantages of lysimeters are that they provide a means of obtaining rapid information on the quality of water before it reaches the water table. Slide 33 indicates the capabilities of lysimeter clusters at various depths. This information could also be obtained from wells below the water table, but the time lag might be months. As with wells, the number of clusters and the frequency of sampling depend upon the size of the site and the amount of information necessary for statistical reliability.

The criteria for groundwater quality are established under federal law and, in some instances, further defined under state laws. Certain aspects of those requirements will be reviewed here.

The Federal requirements apply to "public water systems" as defined in the Public Health Service Act and amended by the Safe Drinking Water Act, PL 93-523. Groundwater resulting from land application is arbitrarily divided into three cases, as indicated in Slide 34.

Case 1: Groundwater which has the potential for being used as a drinking water supply.

Case 2: Groundwater which is used for drinking water supply.

Case 3: Groundwater which has either unpredictable uses or uses other than drinking water supply.

For the most part, those delineations were created to allow flexibility in special situations. The basic water quality requirements, however, apply across the board except for Case 3 which requires a site-by-site evaluation. Also, where natural groundwater quality does not meet federal groundwater requirements, the criteria that apply are that no further deterioration in water quality can result from land application (Slide 35). The specific federal water quality criteria are given in the "National Interim Primary Drinking Water Regulations", which went into effect in June of 1977.

Specific maximum contaminant levels for inorganic chemicals in drinking water are given in Slide 36. Fluorides are treated in a different manner then other inorganics because a small margin separates beneficial levels of fluoride from levels which cause adverse health effects. That fact prompted EPA to define maximum fluoride concentrations in terms of the climate served by the public water system as defined by the mean maximum daily air temperatures of the locality as indicated in Slide 37. The toxic effect of fluoride in drinking water is limited to mottling of dental enamel and minor changes in bone density and there is evidence that these physiological effects are temperature dependent at various concentrations with small margins between beneficial and detrimental effects.

The maximum contaminant levels of organic chemicals in Slide 38 apply only to community water systems.

Samples for turbidity in drinking water are taken at a representative entry point(s) in the drinking water distribution system (Slide 39). In effect, the turbidity requirement specifies that the monthly average may not exceed one turbidity unit. Certain exceptions are recognized, however.

For microbial contaminants federal regulations specify counts of coliform bacteria only. The actual number permitted per count depends on the technique used and on a monthly averaging formula. To avoid irregularities in arriving at average values, the minimum number of samples to be taken for coliform analysis per month has been established and is indicated in Slide 40. Notice that the scale is related to the population served. Further modification of federal requirements are in the process of being enacted or may be expected in the near future. Some likely changes are:

Sodium and sulfates are significant to diets of certain individuals, and discussed in the National Interim Primary Drinking Water Standards. It is recommended that the levels of these substances be made known so that persons susceptible to ill effects can be alerted to high concentrations. Not enough evidence is thought to be available to promulgate standards (Slide 41).

PCB's and asbestos may be subjected to regulations when certain analytical methods, health effects, and environmental occurrence has been evaluated by EPA. Proposed rules were printed in the Federal Register of May 24, 1977.

No federal guidelines have been issued on groundwater monitoring protocol pertaining to the kinds, numbers, or implacements of groundwater monitoring devices to be used at land application sites.

The criteria for waters leaving land application sites has already been stated. Slide 42 indicates the criteria for irrigation waters which will usually apply to wastewater application. This slide indicates the maximum permissible concentrations of inorganic chemicals in irrigation waters.

State water quality regulations, whether for public drinking water or irrigation water, may be more, but not less restrictive then federal requirements (Slide 43). Slide 44 indicates some of the parameters for which there may be state guidelines. For several of these parameters there may be no current federal guidelines at all. For further discussion of some specific state guidelines, including monitoring, refer to Module 16, "Legal Aspects" (Slide 45).

While water quality remains a major concern of monitoring programs, and is the major focus of this lesson, other environmental factors may be of greater or lesser concern to individual sites. Some of these factors represented in Slide 46 may come under regulation, either federal or state, in the future.

A land application site may find it useful to monitor two aspects of air quality. These are aerosols and odors. Aerosols are tiny droplets of water, especially common to high pressure spray systems like the one in Slide 47, spraying cannery wastes. Those droplets can be carried off site by winds. Bacteria and viruses may be contained in these droplets and may result in public health implications. Monitoring both the aerosol drift and the epidemiologic impact of that drift require competencies beyond

routine managerial skills or training. Aerosol generation and monitoring is discussed in Module 9, "Pathogens". This discussion includes experiences from actual systems and indicates research results (Slide 48).

Odors may be very difficult to document or control. Well managed land application sites are usually odorless or, at worst, odorous only occasionally and then only mildly so. This may not be the case, however, with particular types of wastewater and sludges. Slide 49 indicates the most sophisticated piece of equipment generally needed to monitor odors. More sophisticated equipment is available for special cases.

Soils should be subject to routine, periodic analysis (Slide 50). Such analysis could occur on an annual or semi-annual basis in most cases. Planting vegetation known to be particularly sensitive to suspected toxicants can be a "poor man's" monitoring device, but very useful in eliminating the need for much more involved and costly laboratory analyses. A table of a few of the plants sensitive to copper, zinc, or nickel is shown in Slide 51. Even if indicator plants are used, the chemical analyses of soils is usually done by a competent consultant. Soil analysis is important because indicator plants only indicate when a situation has reached a specific threshold. However, site managers need to know the rates of accumulation of potentially toxic materials in the soil.

Slide 52 indicates the biotic aspects of a land application site that a manager may need or wish to monitor. The absence of a healthy well diversified soil community might indicate the onset of a degeneration of the application site. Experts in the surveying of the particular type of operation being conducted, whether it is a farming, forest, or grassland operation, ought to be consulted.

In summary, federal and state regulations indicate the quality of the influent that can be applied to the land, and the water that flows through or under a site. Monitoring is needed to assure that the required degree of treatment occurs and that the public health is protected. Monitoring should also include other aspects of a land treatment site so that the site is more acceptable to a community and so that the site managers can head off a breakdown in the system (Slide 53).

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Booklet to Accompany the A-T
MONITORING AT LAND APPLICATION
SITES
Module 18
January, 1978

Monitoring Considerations for Groundwater[1]

Groundwater Monitoring Guidelines on Land Waste Disposal Facilities

Monitoring Objectives

The function of a groundwater monitoring program for proposed land disposal facilities is to confirm judgements made during design. This is to be accomplished by a continuing long-term in-depth hydrogeologic study regarding the performance of the system and its influence on surrounding groundwater conditions. This applies to:

1) Wastewater treatment lagoons
2) Wastewater storage lagoons
3) Land irrigation systems
4) Large subsurface disposal fields
5) Wastewater sludge disposal sites
6) Industrial waste concentrations disposal sites

At all such existing sites groundwater monitoring programs are needed to determine the influence of disposal practices on the groundwater resource.

Design of Monitoring Wells

Monitoring wells must be designed and located to meet the specific geologic and hydrologic conditions at each site. Consideration must be given to the following:

1) Geological soil and rock formations existing at the specific site.
2) Depth to an impervious layer.
3) Direction of flow of groundwater and anticipated rate of movement.

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[1] Blakeslee, 1973

4) Depth to seasonal high water table and an indication of seasonal variations in groundwater depth and direction of movement.
5) Nature, extent, and consequences of mounding of groundwater which can be anticipated to occur above the naturally occurring water table.
6) Location of nearby streams and swamps.
7) Potable and nonpotable water supply wells.
8) Other data as appropriate to the specific system design.

Groundwater quality should be monitored immediately below the water table surface near the application site as pollutional materials entering the groundwater system may have a tendency to remain in the upper few feet. Applied wastewater will generally be depressed within the groundwater system as the material travels away from the site. The need for sampling at more than one depth within a groundwater system will depend upon geologic conditions and distance from the pollutional source. Definition of the flow system with depth will be necessary to properly determine the depth to be monitored, especially when mounding is superimposed on the existing system.

Additional design and construction considerations are:

1) Monitoring wells in fine textured soils will require special construction such as gravel packing around the screen.
2) Wells constructed to a depth of 20' or more should be 4" in diameter to facilitate use of submersible pump equipment for sample collection unless alternative sampling methods are approved by the reviewing agency.
3) Construction should be by a registered well driller or contractor covered under Act 315, PA of 1969 using approved modern construction

methods.

4) Casings shall be grouted and capped and a cap-locking device provided. Use of a vented cap is desirable but care must be taken to prevent introduction of contaminants through such vents.
5) The well casing should be protected against accidental damage and adequately marked to be clearly visible during winter and summer conditions.
6) Each well should be labeled and identified (owner, owners address, well number, use of well and warning).
7) If a monitoring well is to be permanently abandoned, approved procedures are to be followed.

Location

Groundwater monitoring wells must be located so as to detect any influence of wastewater application on the groundwater resource. A minimum of one groundwater monitoring well must be provided in each direction of groundwater movement near the pollutional source with adequate consideration being given to possible changes in groundwater flow due to mounding effects. The orientation and spacing of multiple wells shall be determined by conditions at each site.

Water Level Measurement

The following considerations apply with regard to water level measurement:

1) Water levels should be determined by methods giving precision to 1/8 inch or 0.01 feet. (Example - wetted tape method)
2) Measurements should be made from the top of the casing with the elevation of all casings in the monitoring wells system related to a permanent reference point, using USGS datum.

3) Water level measurements are to be made under static conditions prior to pumping for sample collection.

4) Monitoring wells should be installed early in the construction sequence and monthly water level readings obtained during the construction period and during the first two years of wastewater system operation to provide background information. Subsequent water level measurement frequency should be in accordance with a schedule established on a case by case basis.

5) All wells should be securely capped and locked when not in use.

Water Sampling

Background water quality. A minimum of three monthly samples should be collected from each monitoring well prior to placing the storage or disposal facility in operation. In cases where background water quality adjacent to the site may be influenced by prior waste applications, provision of monitoring wells or analysis of water quality from existing wells in the same aquifer beyond the area of influence will be necessary.

Operating Schedule. Samples should be collected monthly during the first two years of operation. After the accumulation of a minimum of two years of groundwater monitoring information, modification of the frequency of sampling may be considered upon written request.

Sample Collection

1) A measured amount of water equal to or greater than three times the amount of water in the well and/or gravel pack should be exhausted from the well before taking a sample for analysis. In the case of very low permea-

bility soils the well may have to be exhausted and allowed to refill before a sample is collected.

2) Pumping equipment shall be thoroughly rinsed before use in each monitoring well.
3) A pressure tank shall not be used with a sampling system since the water in the pressure tank would be particularly difficult to exhaust.
4) Water pumped from each monitoring well should be discharged to the ground surface away from the wells to avoid recycling of flow in high permeability soil areas or soil erosion.
5) Samples must be collected, stored, and transported to the laboratory in a manner so as to avoid contamination or interference with subsequent analyses.

Sample Analysis

Water samples collected for background water quality should be analyzed for the following: (Note: Parameters for groundwater monitoring at industrial waste disposal sites must be established on an individual basis depending on the composition of the wastes applied).

1) Chloride
2) Specific conductance
3) pH
4) Total hardness
5) Alkalinity
6) a. Ammonia nitrogen
   b. Nitrate nitrogen
   c. Nitrite nitrogen
7) Total phosphorus
8) Methylene blue active substances
9) Chemical oxygen demand*

*Use of low concentration C.O.D. analysis methods per current edition of Standard Methods may be necessary.

10) Any heavy metals or toxic substances found in the applied wastes.

After adequate background water quality information has been obtained, a minimum of one sample per year, obtained at the end of the irrigation season in the case of seasonal operations, should be collected from each well and analyzed for the above constituents.

All other water samples collected in accordance with the operating schedule should be analyzed for chlorides and specific conductance as indicators of changes in groundwater quality resulting from the wastes applied. If significant changes are noted in chloride and/or specific conductance levels, samples should immediately be analyzed for the other parameters listed above to determine the extent of water quality deviation from background levels.

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